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SPACE ASTRONOMY

OF THE

STEWARD OBSERVATORY

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

IRIS PHOTOMETRY ON SMALL SCALE PLATES

T 67-10

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by

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IRIS PHOTOMETRY ON SMALL SCALE PLATES

To determine the precision obtainable in normal iris photometry of stars on very small scale direct sky photographs, a series of measurements were made on four plates with the following objectives:

1. Determine the intrinsic accuracy possible in normal isolated individual stars.
2. Determine how general unresolved background and close companion stars effect the photometry.

The four low scale plates utilized were selected from a set of plates of the region of the Small Magellanic Cloud obtained at Mount Stromlo in 1959. This region was selected because data from several telescopes was available for comparison. The camera utilized for the low scale plates is an 8-inch F/1 Meinel-Pearson Schmidt with a 12^{o} field. Plate scale is 18 arc minutes/mm. Standard B or V plates were not available, but the combinations of plates and filters closest to these wavelength bands are sufficient for the purpose of this study. Table I contains the basic data on the four low scale plates and several comparison plates used. "Range" is discussed later in this report. The filters are in the English Chance series, except the U2557 plate which utilized a Schott GG-14 filter.

Stars from studies in the SMC and nearby 47 Tucanae were used as magnitude standards for measurement on each plate. All stars which could be distinguished from the background were utilized. Table II contains the listing of stars, their adopted V and B magnitudes, the iris readings for each F/1 camera plate, and references to the sources of the V and B photometry. The table also contains a "class" for each star which is a measure

TABLE I

Basic Plate Information

NO.	EMULSION	FILTER	λEFF(EST)	BANDWIDTH	EXPOSURE	REF MAG	RANGE
795	103a-O	Corr Plate	4500	broad	90^{s}	B	±.09
796	103a-O	OY-8	5000	narrow	20^{m}	B:	±.05
824	103a-D	OY-8	5600	broad	$3^{m}10^{s}$	V	±.07
798	103a-D	OY-1	6100	moderate	7^{m}	V:	±.07
U2557	103a-D	GG-14	V	V	12^{m}	V	±.02
S1193	103a-D	OY-4	V	V	60^{m}	V	--
S1302	103a-D	OY-4	V	V	60^{m}	V	--

TABLE II Stellar Measurements

STAR	V	B	CLASS	IRIS READING 795	796	824	798
SMC-A	6.84	6.95	5	1492	1432	1500	1555
SMC-B	7.11	7.18	5	1486	1432	1519	1555
SMC-D	7.64	8.97	8	1515	1426	1502	1520
SMC-E	7.73	8.83	6	1611		1554	1578
SMC-F	7.80	8.68	4	1606	1509	1553	1588
SMC-G	8.05	8.57	10	1537	1428	1524	1562
SMC-H	8.40	9.38	10	1544	1419	1516	1542
47-g	8.46	8.93	2	1618	1552	1590	1632
SMC-I	9.04	9.90	6	1625	1521	1608	1617
121-A	9.06	9.96	1	1679	1611	1631	1662
47-a	9.52	10.59	2	1704	1594	1632	1661
SMC-J	9.53	10.04	1	1672	1593	1656	1663
SMC-K	9.73	10.05	6	1646			1659
SMC-L	9.74	10.16	3	1692	1590	1658	1684
SMC-M	9.76	10.13	4	1696	1588	1639	1654
SMC-N	9.79	10.79	3	1727	1610	1646	1668
SMC-O	9.89	10.40	5	1679	1578	1620	1666
HD7583	10.13	10.28	2	1666	1580	1678	1715
121-B	10.21	10.69	1	1706	1645	1689	1713
SMC-P	10.25	10.43	4	1658	1601	1658	1680
SMC-Q	10.56	11.73	4	1731	1633	1666	1676
SMC-R	10.58	11.32	8	1635	1509	1592	1601
121-D	10.66	11.72	1	1766	1690	1705	1715
HD6884	10.73	10.77	8			1601	1660
SMC-T	10.74	11.17	4	1674	1620	1673	1676
HD5291	10.75	10.77	15	1498	1338	1463	1551
SMC-V	10.87	11.33	3	1742	1624	1697	1721
HD7099	11.00	10.93	6	1706	1562	1653	1712
SMC-c	11.28	11.80	6	1739	1599	1664	1711
SMC-d	11.30	11.42	5	1725	1614	1670	1732
SMC-e	11.38	11.36	10	1609	1531	1629	1676
SMC-f	11.53	12.06	3	1789	1690	1716	1759
SMC-g	11.58	11.74	6				1748
47-d	11.73	12.25	4	1750	1686	1711	
47-	11.78	13.38	6	1786		1688	1739
121-E	11.81	12.70	3	1782	1719	1728	1737
121-F	11.82	12.46	1	1788	1737	1748	1762
121-G	11.84	12.36	1	1770	1732	1740	1767
47-	12.36	13.68	7		1681		1706
121-H	12.46	13.17	3	1791			1759
47-X	12.48	13.27	2	1792	1752	1748	1781
121-I	12.70	13.26	3	1772			1762
121-K	13.04	13.57	1	1795	1786	1773	1785
47-b	13.06	14.13	2		1750	1759	1789
121-L	13.08	13.95	1	1804	1778	1769	1792
47-p	13.12	13.99	6		1652		1741
47-l	13.32	14.40	3	1784			1760
121-M	13.42	14.06	1	1813	1780	1777	1795
121-N	13.44	14.19	2		1773		1796
121-O	14.38	15.11	1	1822		1801	1820
121-P	14.76	15.44	1	1821	1794	1809	1820
				1850	1850	1850	1850

Background

SMC Arp, A.J. 63, 118

121 Tifft, M.N. 125, 199

HD Buscombe, Kennedy, RASC 56, 113

47 Wildey, Ap.J. 133, 430

of the degree of background enhancement or crowding of each star. Class 1 stars are well away from the SMC and nearby companions. By classes 8-10 the stars lie well within the obvious halo of the SMC. One star in the center of the SMC was classified 15.

The iris photometry was carried out on the Cuffey iris photometer at the Steward Observatory. For each plate, the clear background reading was placed at a standard level. Five settings on each star were made to form the averages contained in Table II. Table I contains the approximate iris range between least and greatest reading on each star averaged over all stars measured on a given plate. This is an indication of the internal measuring consistency and has been converted to magnitudes at the middle of the magnitude range measured. Single measurement errors from setting are seen not to exceed about 0.07 magnitude, and with five measures the setting errors are well below the intrinsic plate errors discussed below.

For each plate a calibration curve between magnitude and iris reading was drawn for class 1 stars to determine the performance of photometry on isolated stars. The deviation of stars of other classes from the basic class 1 curve then measures background enhancement effects. Figures 1-4 show the complete set of measurements. Table III summarizes the quantitative results for magnitude residuals as a function of class in the iris range indicated. The number of stars in each mean is given in paranthesis. The toe region of the curves has been omitted since such measures are intrinsically much less accurate. The table also contains the mean absolute residual of class 1 stars, denoted 1*. There is a correlation of residuals with exposure time in that longer exposures tend to minimize both setting range and final mean residuals. This is logically expected since the longer exposures tend to produce more smoothly blurred image spots.

TABLE III

Mean Magnitude Residuals

PLATE	1	2-3	4-5	6-7	8-10	IRIS RANGE	1*
795	0.0 (9)	0.3 (12)	0.5 (8)	0.5 (6)	2.4 (2)	1600-1815	0.26 (9)
796	0.0 (8)	0.6 (11)	0.8 (8)	2.1 (5)	2.9 (2)	1500-1780	0.12 (8)
824	0.0 (9)	0.4 (10)	0.9 (7)	1.3 (4)	2.3 (3)	1580-1800	0.07 (9)
798	0.0 (9)	0.4 (14)	0.9 (6)	1.0 (8)	2.2 (3)	1600-1800	0.14 (9)

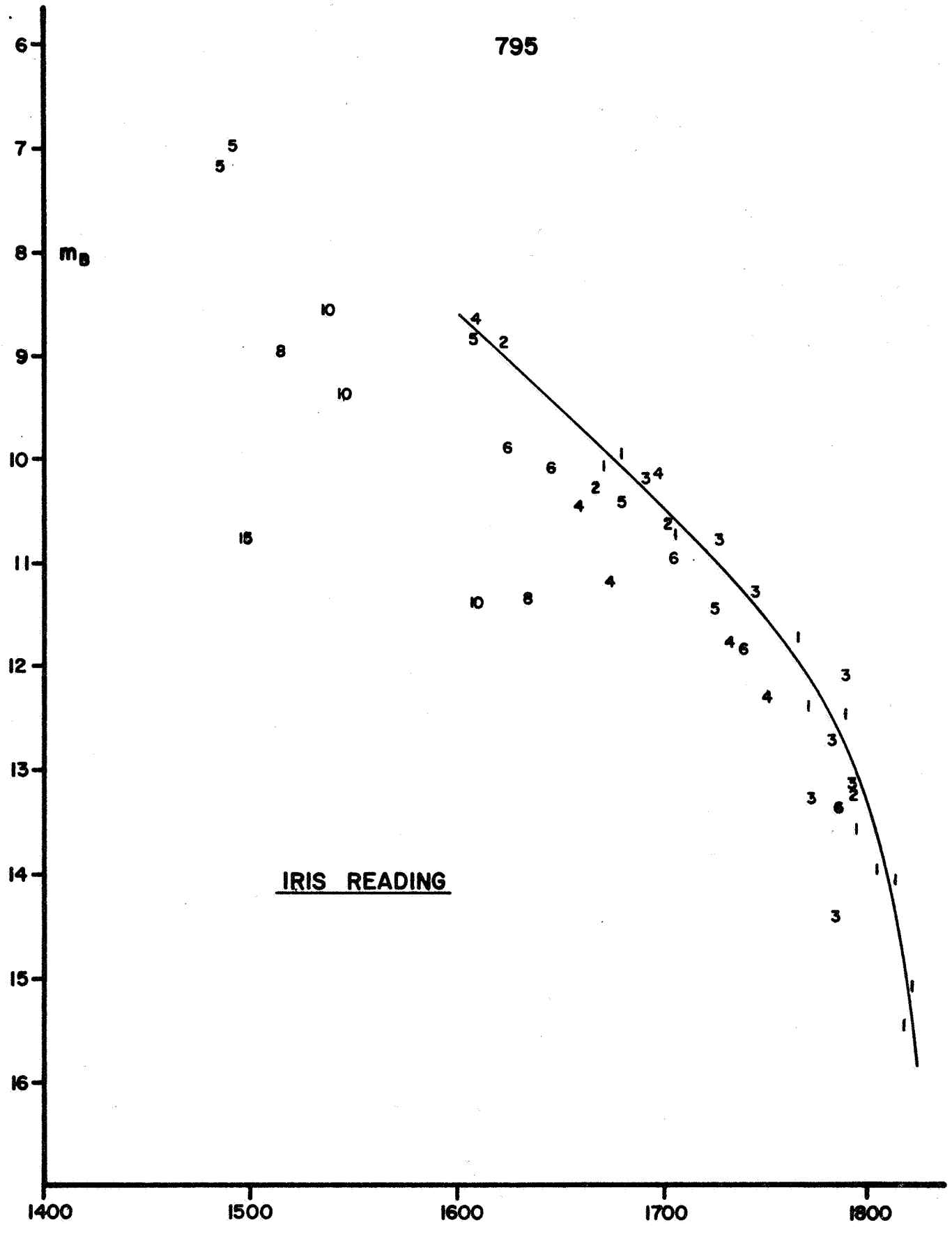

795
m_B
IRIS READING
6
7
8
9
10
11
12
13
14
15
16
1400
1500
1600
1700
1800

FIGURE 1

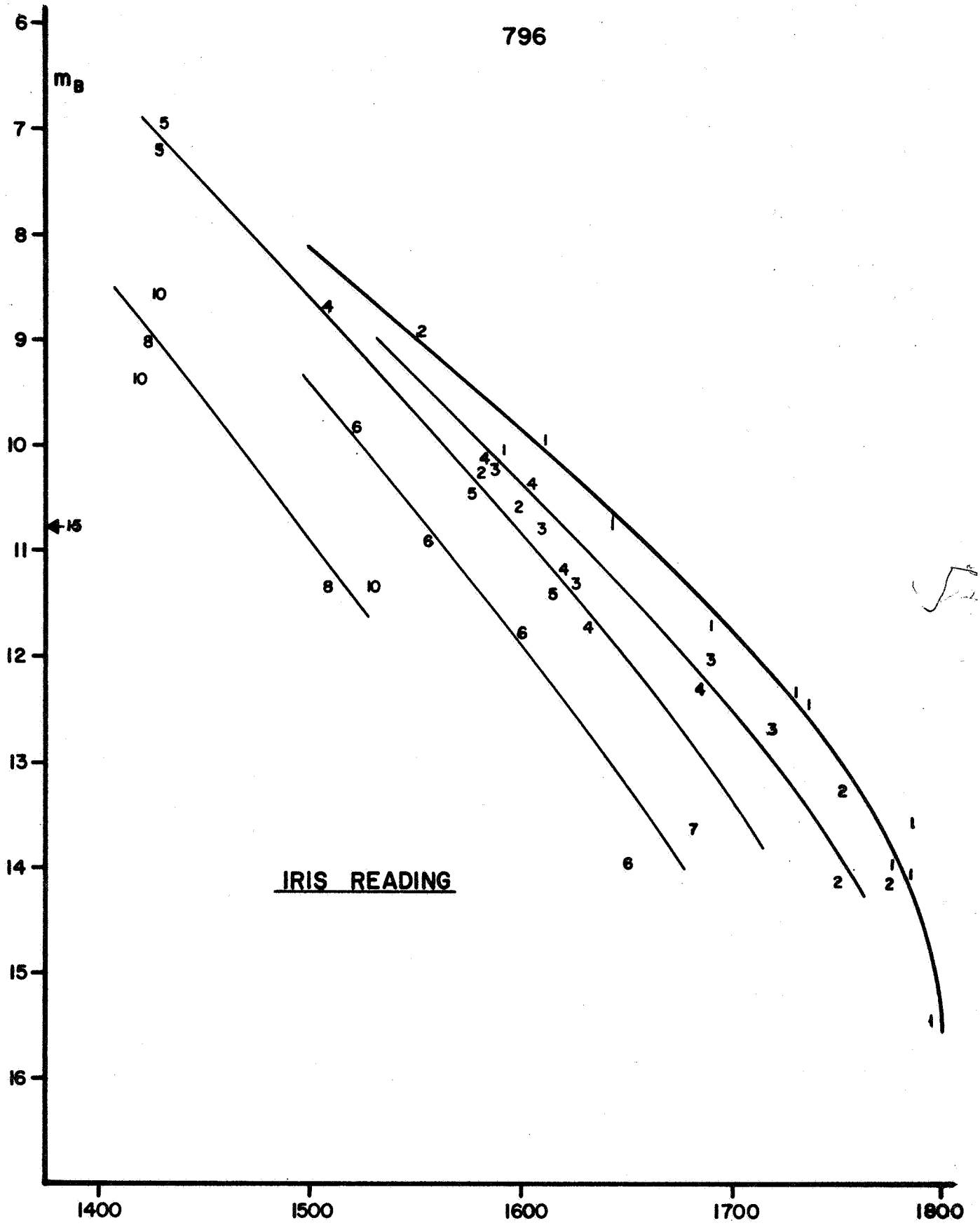

m_B
6
7
8
9
10
11
12
13
14
15
16
15
1400
1500
1600
1700
1800
IRIS READING

FIGURE 2

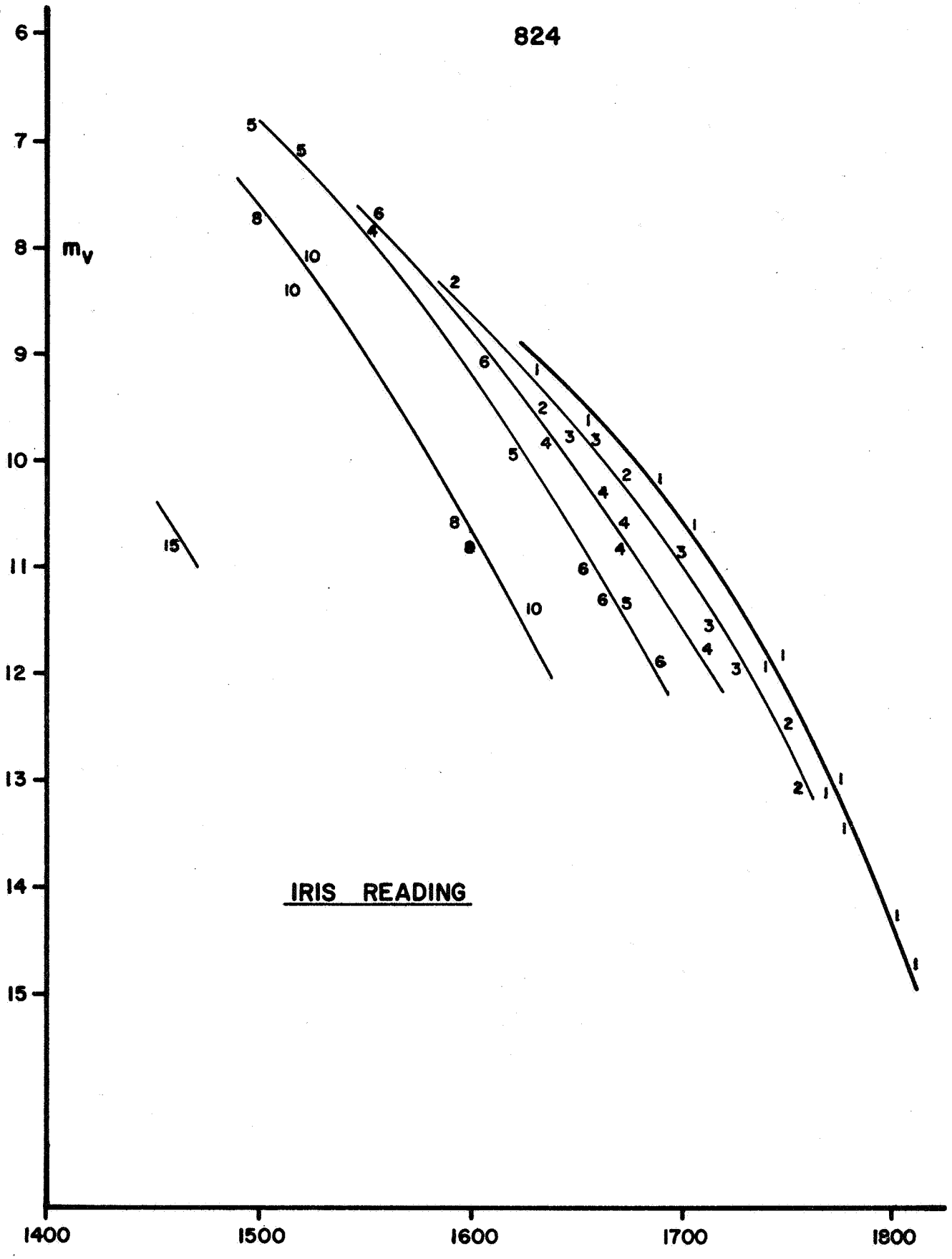


FIGURE 3

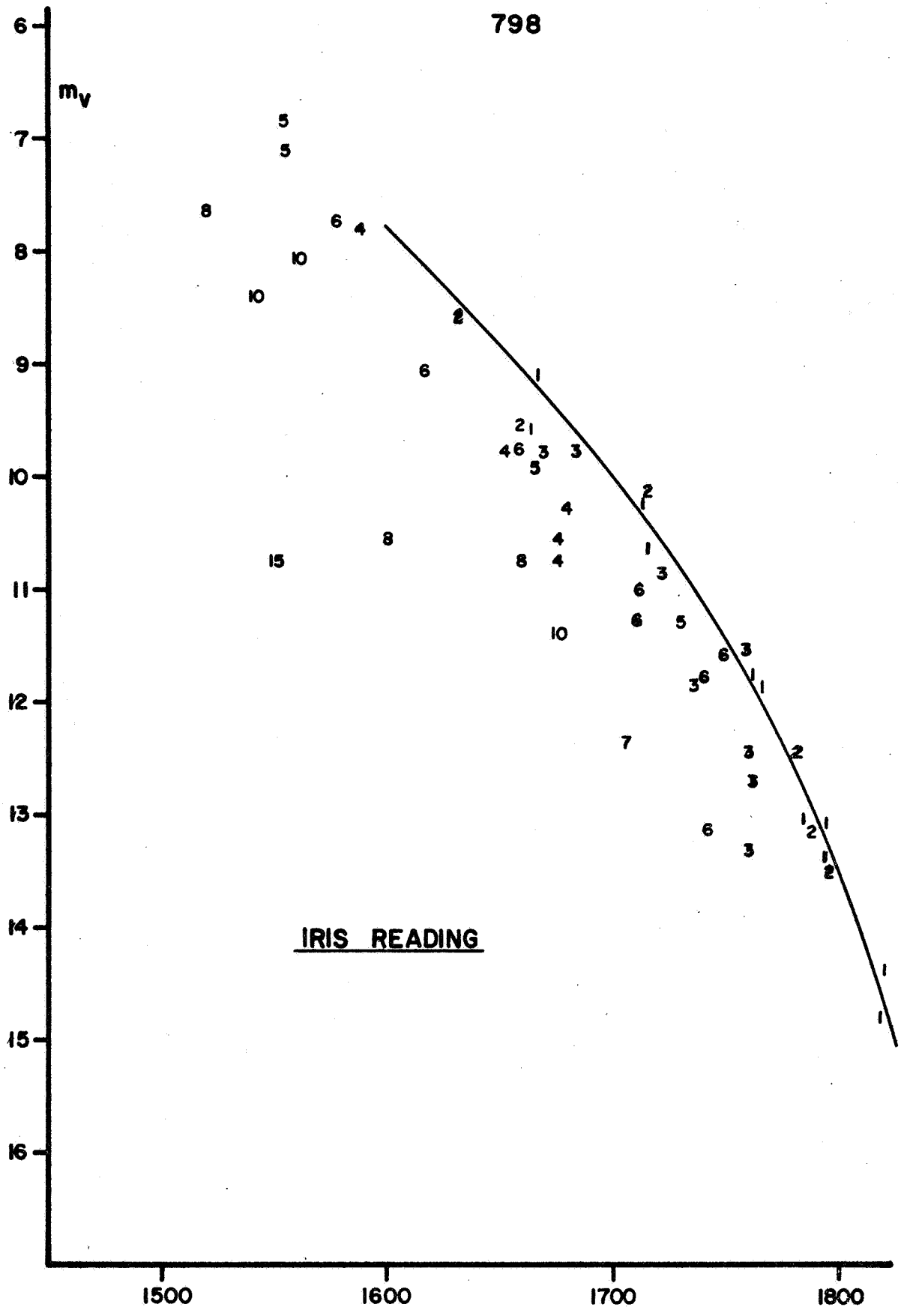


FIGURE 4

From Table III it is apparent that photometry to about 10% accuracy can be expected from photographic iris photometry of isolated stars. Background enhancement and crowding will produce serious systematic errors. Systematic corrections as a function of background level adjacent to the stars should improve measurement accuracy although further quantitative examination on this point is required. Qualitative assignment to classes based upon background clearly produces a smooth ordering of residuals. There appears to be less enhancement on the normal short blue exposure than on the normal yellow exposure. This is logical on the basis that the SMC halo is dominated by yellow (older) stars which are less effective in enhancement at short wavelengths. Enhancement is greatest on the narrow band long exposure where the SMC has been brought out strongly by improving its contrast against the sky. The reduction of galaxy halo region enhancement at broadband shorter wavelengths should be particularly effective in the ultraviolet and should permit fairly accurate photometry close to the Magellanic Clouds.

For comparison purposes, a V plate (U2557) taken with the Uppsala F/3.5 Schmidt telescope at Mount Stromlo was measured in the NGC 121 region. This 26-inch Schmidt has a plate scale of 1.5 arc minutes/mm. The calibration curve is shown in Figure 5. Table IV contains the iris data and Table V contains summary data on measuring range and final mean residuals for the Uppsala plate along with the mean F/1 Schmidt data. The Uppsala plate was measured in identical fashion to the F/1 Schmidt plates. One star, J, plotted with a cross is clearly enhanced by its proximity to NGC 121 while all other stars are well in the clear.

As a second comparison, V plates of NGC 121 taken with the 74-inch reflector at Mount Stromlo were utilized. Two types of plates are

FIGURE 5

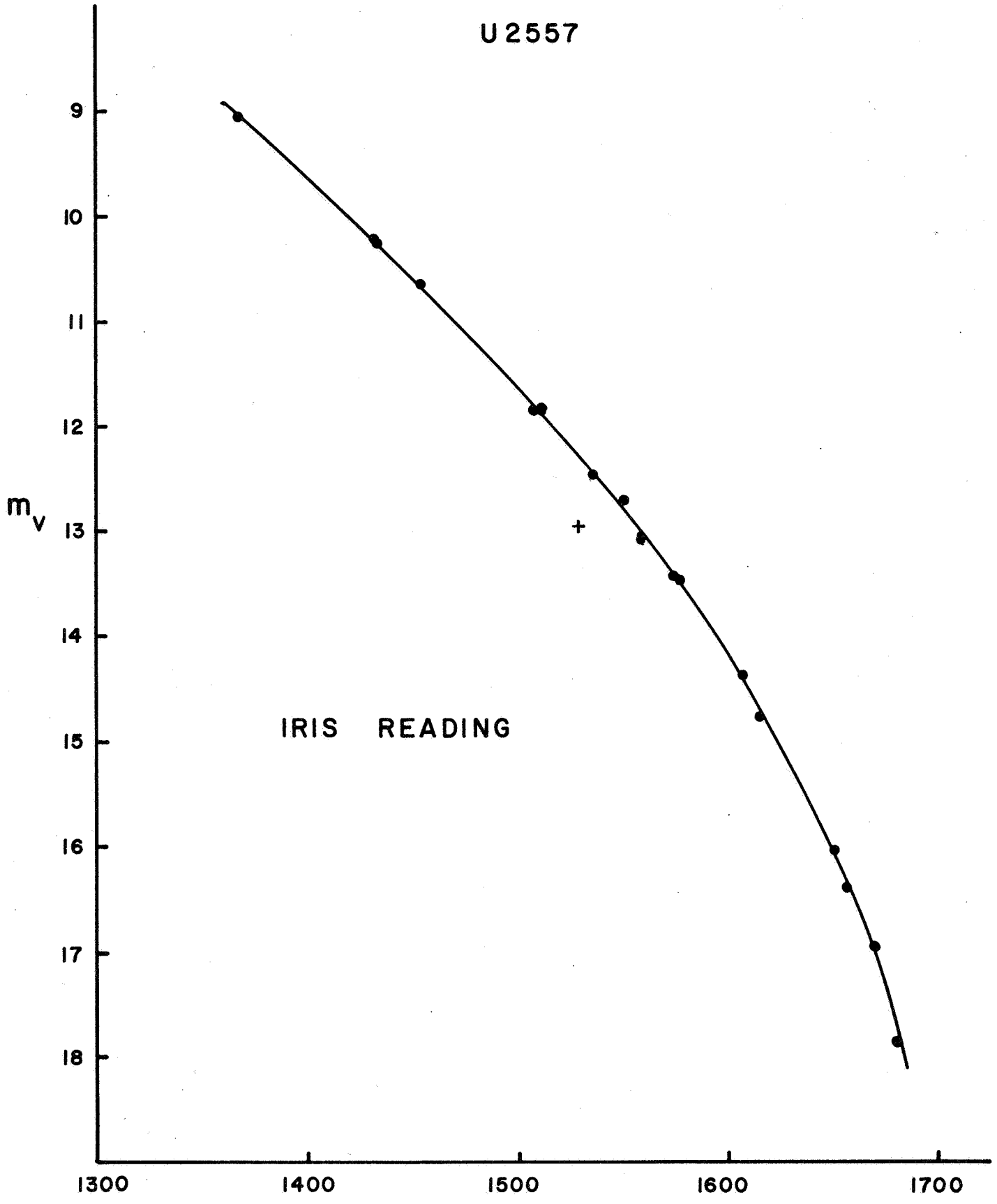

U2557
9
10
11
12
13
14
15
16
17
18
m_v
IRIS READING
1300
1400
1500
1600
1700

TABLE IV

Comparison Photometry

STAR	V	V'	IRIS READING U2557	S1186	S1302
121-A	9.06		1368		
B	10.21		1432		
C	10.27		1434		
D	10.66		1455		
E	11.81	11.77	1512	1870	
F	11.82	11.79	1512	1853	
G	11.84	11.81	1508	1860	
H	12.46	12.42	1536	1730	
I	12.70	12.67	1550	1680	
J	12.96	12.90	1529	1651	
K	13.04	13.01	1560	1619	
L	13.08	13.04	1560	1605	
M	13.42	13.39	1574	1540	
N	13.44	13.40	1577	1548	
O	14.38	14.34	1607	1379	
P	14.76	14.73	1615	1328	
Q	16.03	16.00	1650	1111	2169
R	16.40	16.37	1657	1013	1956
S	16.97	16.94	1670	895	1700
T	17.29	17.21		888	1700
U	17.64	17.61		776	1470
V	17.66	17.59		791	1499
W	17.88	17.83	1680	741	1364
X	18.31	18.25		659	1119
Y	18.84	18.77		618	1008
Z	19.54	19.51		573	795
α	19.80	19.77		575	801
β	20.22	20.18			750

TABLE V

Comparative Photometric Performance

TELESCOPE	RANGE	MEAN RESIDUAL	IRIS RANGE
8-Inch F/1 Schmidt	±0.07	±0.15	---
26-Inch F/3.5 Schmidt	±0.02	±0.04	1300-1625
74-Inch at 45-Inch F/8 Newtonian		±0.03	1900-1300

available, F/8 plates taken with a 45-inch stop (S1186) and F/5 plates at full aperture (S1302). Plate scale is 22 arc seconds/mm. These plates were not available for measurement for this program; original measurements from the NGC 121 analysis (Tifft, M.N. 125, 199, 1963) were utilized. The procedure of measurement was very similar but range was not recorded. The iris photometer used was the Mount Wilson and Palomar Observatory Sartorius instrument. Figures 6-7 give calibration curves while Table V contains the mean residuals, and Table IV the raw iris data. A very slight color equation applies to the 74-inch V measures due to the OY-4 filter match to V. Thus, $V' = V + 0.05(B-V)$ is used in the 74-inch tabulations. The mean residual is not calculated for the full aperture 74-inch data since only stars below magnitude 15-16 are suitably exposed for measurement. At these faint limits, the calibration photoelectric photometry is less accurate than the photographic photometry. A comparison of figures 6 and 7 show that the stars deviate from the mean curves in the same manner for both plates. There is no reason to expect the intrinsic accuracy of the iris photometry to differ for the two 74-inch plates. A significant portion of the residuals of the brighter stars may be the result of photoelectric magnitude uncertainties, perhaps 2%.

The general conclusions to be drawn from this study may be briefly summarized as follows:

1. Iris photometry is a valid means of photographic photometry on plates of all scales from the wide field fast Schmidt to the large scale reflector in a small detailed field.
2. Except near the plate limit, iris photometry intrinsic accuracy (single plate magnitude for a single star) is about 1-3% for large scale telescope plates. Accuracy decreases only slightly,

FIGURE 6

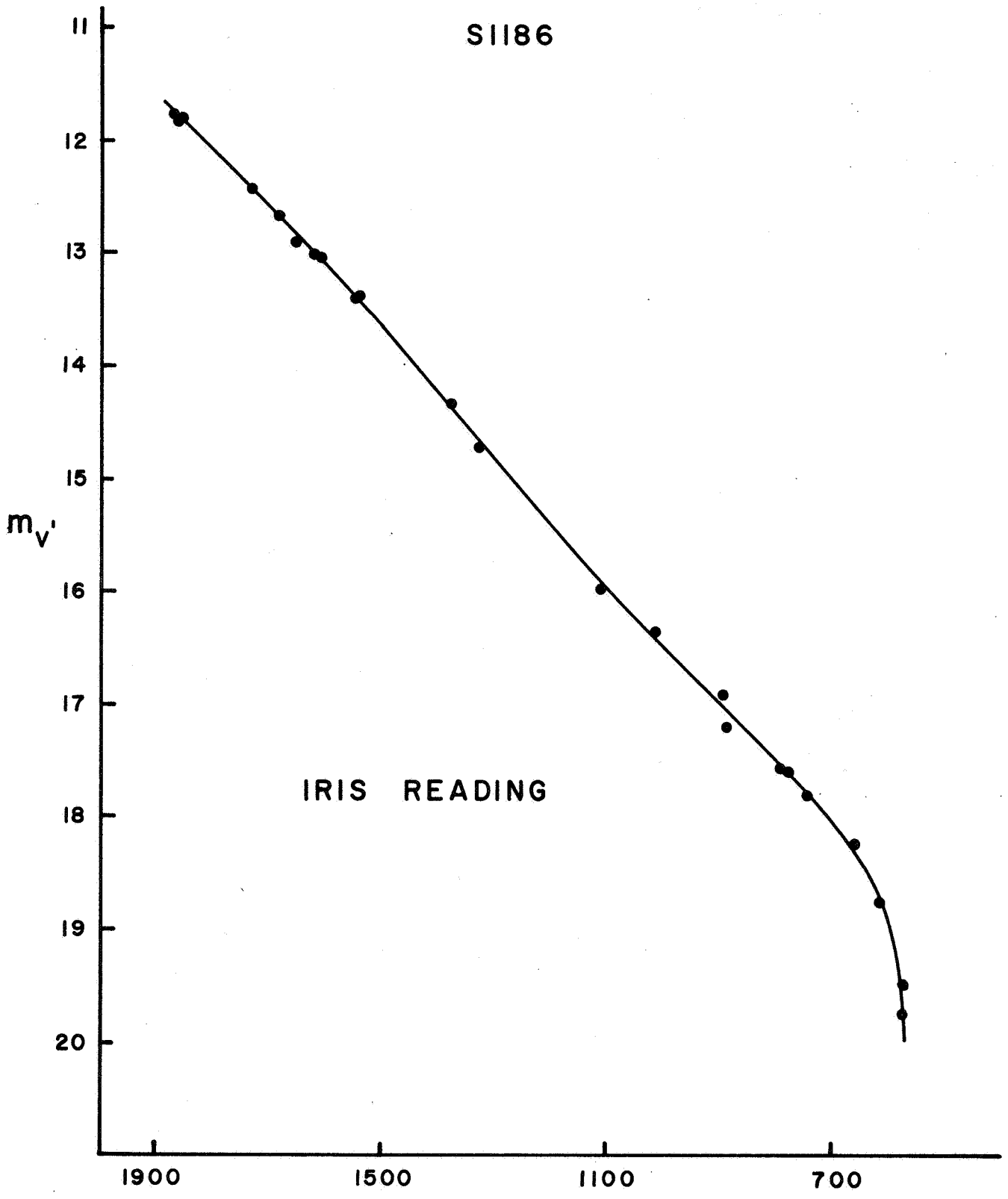
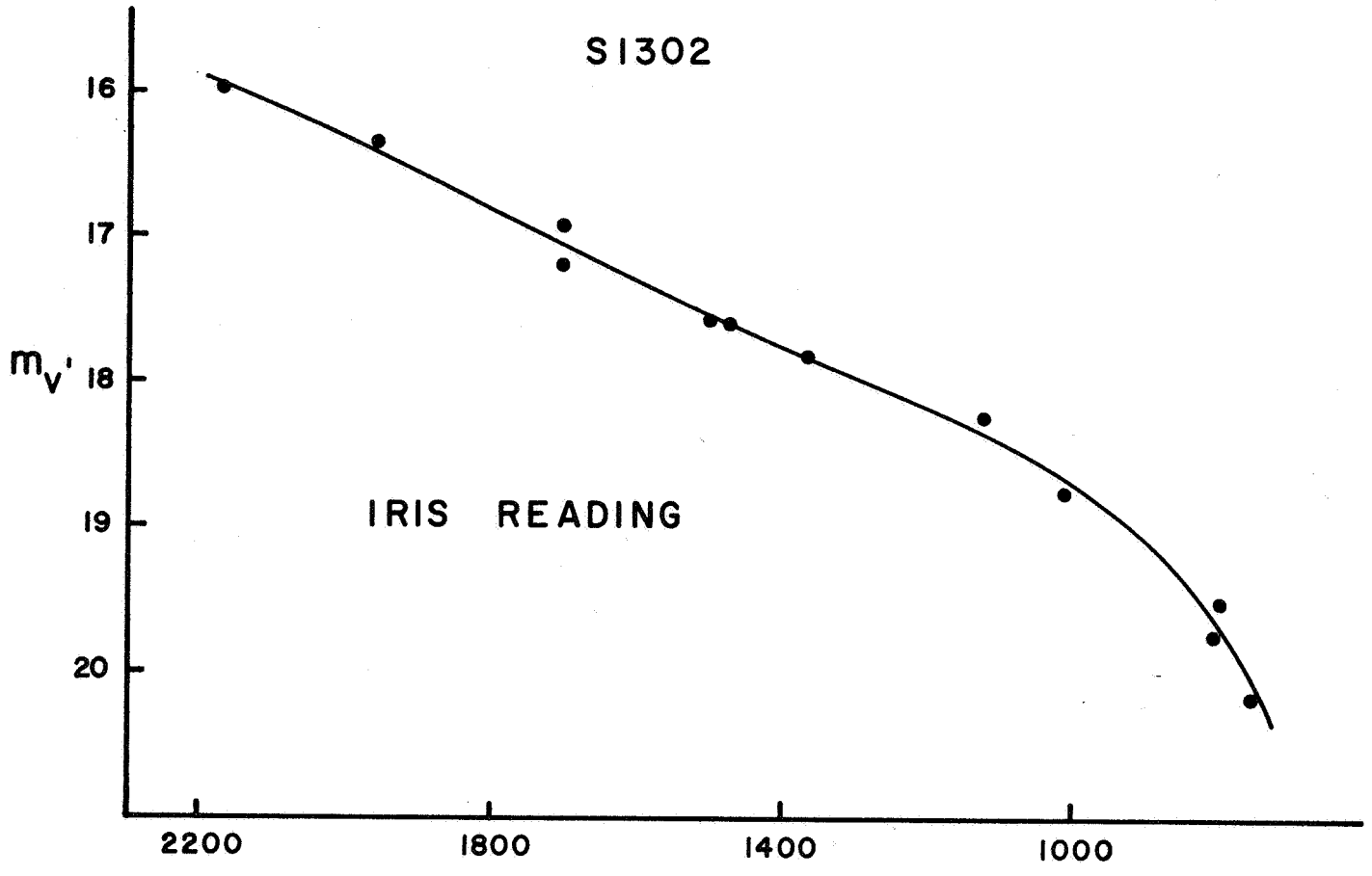

S1186
11
12
13
14
15
16
17
18
19
20
$m_{v'}$
IRIS READING
1900
1500
1100
700

FIGURE 7



to 2-4% for conventional Schmidt imagery, and drops to 10-15% for the very wide field fast Schmidt systems. There is a slight tendency for short exposures to have lower intrinsic accuracy than longer exposures.

3. Errors from slight variations in centering on images is less than intrinsic plate errors (running about 1/2) such that taking the mean of several settings can render this error insignificant.

4. Unresolved background and close companions will effect the photometry appreciably; however, the effects are visually apparent, and isolated stars can be readily distinguished for photometry. For slightly enhanced stars, systematic corrections based upon adjacent background readings are likely to be quite effective. Background enhancement effects show a wavelength dependence with shorter wavelengths providing less enhancement in the vicinity of the SMC. Residual crowding of stars is probably a large part of the reason for the general growth of error with plate scale.

Figure 8 contains photomicrographs of the images of several stars on some of the various types of plates used in this study. All plates were of the 103a variety, hence, have similar grain structure. The scale of all the photographs is indicated by a scale in 0.1 mm units.

The iris photometry and data tabulation for this program was carried out primarily by Mr. David Webb, graduate assistant in the Space Astronomy Group during 1966-67.

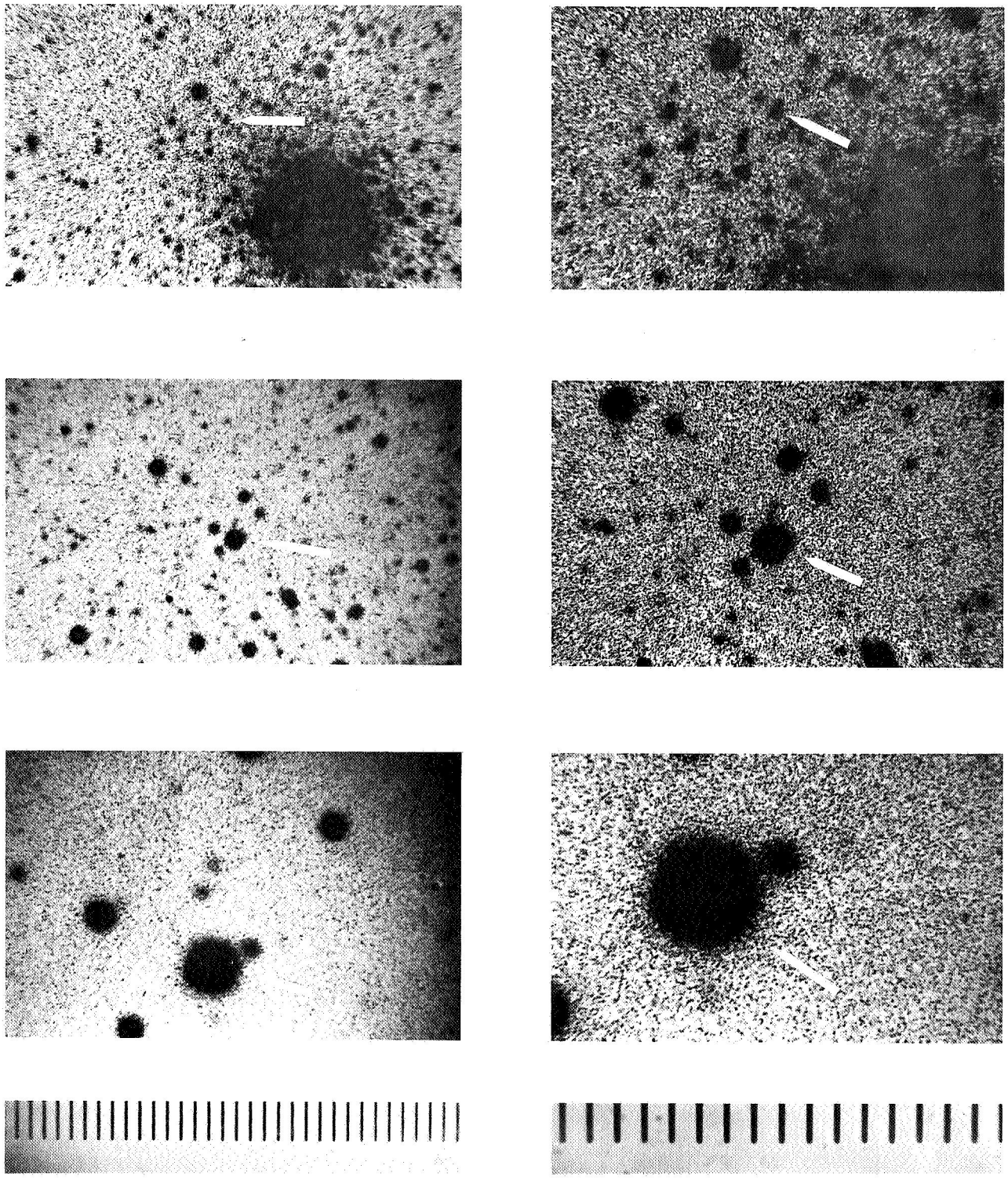


FIGURE 8. Photographs of Plates Used in the Study

Top Row, F/1 Schmidt; Middle Row, Uppsala Schmidt; Bottom Row, 74-inch Reflector. Two magnifications of each plate are included. Below each column a scale in 0.1 mm units is shown. A mark on each picture identifies a star in common.